Request for Patent
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To Director-General of the Japan Patent Office Takehisa Ido
1. Title of the Invention
PHOTOSYNTHESIS REACTOR
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Specification

1. Title of the Invention

PHOTOSYNTHESIS REACTOR

2. Claim

Photosynthesis reactor, comprising:

a tubular body for containing substance to be reacted, the tubular body provided with a reflecting mirror on the circumferential surface thereof;

a laser emitting apparatus installed on the side face of the tubular body over a window; and

an oscillator for periodically oscillating a laser beam inside the tubular body, the oscillator attached to the laser emitting apparatus.

3. Detailed Description of the Invention

This invention relates to improvement of a photosynthesis reactor using a laser beam.

Photosynthesis reactions are reactions which are performed with high energy light such as sunlight and a mercury-vapor lamp light, having been known since old times. In general, the reaction is accelerated in proportion to the number of photons.

The kinds and the energy values of light beams are presented. As apparent from these, light energy increases in the order, sunbeams < mercury lamp light < laser.

For this reason, the laser is spotlighted as an optimal energy source for future photosynthesis, and various utilizing methods have already been tried out.

Kinds of light	Photon/sec·cm2·100angstrom
Sunlight	9.4×10^14
High-pressure mercury-vapor lamp light	10^19
Light of a flash photolysis apparatus	10^21
YAG laser	1×10^21
Ruby laser	3×10^27
Pulsed laser	1×10^24

However, a distinctive feature of laser is that light can be concentrated in beam form. Since the directivity of laser lights cannot be

controlled in ones which have been developed until now, there is a drawback that efficient treatment cannot be performed for a large amount of substances to be reacted.

On the other hand, air pollution by various kinds of exhaust gases becomes an earnest social problem today. It is demanded in all directions to develop an apparatus which can reliably and economically treat the pollutant such as sulfur oxides, nitric oxides, and carbon monoxide.

Considering such circumstances, the present inventor has succeeded in developing a practical apparatus which efficiently allows for photosynthetic reaction in the large amount of substances to be reacted, including exhaust gases, by the use of a mechanism by which a laser beam is freely oscillated inside a tubular body.

This photosynthetic reactor is characterized by including: a tubular body for containing substance to be reacted, the tubular body provided with a reflecting mirror on the circumferential surface thereof; a laser emitting apparatus installed on the side face of the tubular body over a window; and an oscillator for periodically oscillating a laser beam inside the tubular body, the oscillator attached to the laser emitting apparatus.

In the first place, before the description of examples, taking three substances for instance, i.e., carbon monoxide, sulfurous acid gas, and nitric oxides, the photoreaction mechanisms of these will be described.

Firstly, carbon monoxides react with a large number of oxygens in the presence of a trace quantity of chloride as shown below, and is oxidized to carbon dioxide.

In this case, the chlorides are excited by light of 4050 to 4360 angstrom.

$$Cl_2 + h\nu \rightarrow 2\,Cl$$
$$CO + Cl + Cl_2 \rightarrow COCl + Cl_2$$
$$COCl + Cl_2 \rightarrow COCl_2 + Cl$$
$$COCl_2 + O_2 \rightarrow CO_2 + ClO$$
$$CO + ClO \rightarrow CO_2 + Cl$$

$$2\,CO + O_2 \xrightarrow[Cl]{} 2\,CO_2$$

Next, sulfurous acid gas is oxidized to sulfur trioxide by light of

3200 angstrom. In this event, the existence of moisture speeds up the reaction.

This is one of principal causes of photochemical smog that often makes a noise in the world today. It is noted that if sulfurous acid gas is converted into sulfur trioxide, it can then be easily removed by washing.

Concerning nitric oxides, it is somewhat complicated. There is a trend to convert boiler fuels to natural gas, avoiding generating above described sulfurous acid gas. In this case, nitric oxides are generated, depending on combustion conditions.

Photochemical reactions are initiated in the nitric oxides by light of respective wavelengths below, and they are ultimately decomposed into nitrogen and oxygen.

$$N_2O_5 \xrightarrow{\substack{(2800\ \text{angstrom}) \\ (2650\ \text{angstrom})}} N_2O_4 + O_2$$

$$N_2O_4 \xrightarrow{\substack{(3130\ \text{angstrom}) \\ (2800\ \text{angstrom})}} NO + O_2$$

$$N_2O \xrightarrow{(\text{Al flare})} NO + N_2 + O_2$$

$$NO \xrightarrow{(1832\ \text{angstrom})} N_2 + O_2$$

Nitrogen monoxide alone is hard to be absorbed by water or an alkaline water solution. On the other hand, it is relatively easy for nitrogen dioxide (NO_2). However, as well known, the coexistence with nitrogen monoxide causes the absorptivity to increase further. Accordingly, if approximately 50% of nitrogen monoxides are oxidized to nitrogen dioxides, remaining nitrogen monoxides will be absorbed, thus making it possible to significantly reduce the nitric oxides contained in exhaust gases.

These reactions follow the equations below.

$$NO + 1/2\ O_2 \rightarrow NO_2$$

$$NO + O_2 \rightarrow NO_2 + O_2$$

$NO + NO_2 + 2\ NH_4OH \rightarrow 2\ NH_4NO_2 + H_2O$

The photochemical reaction mechanisms of carbon monoxide, sulfurous acid gas, and nitric oxides have been described above. An improvement by the present invention is that these reactions have been made suitable for practical use by efficiently initiating them using laser beams. This will be described below with two examples in reference to the drawings.

In Figs. 1 and 2, 1 designates a transparent reaction cylinder, 2 designates a reflecting mirror, which covers the outside of the cylinder 1. A laser emitting apparatus 3 is installed on the cylinder over a window 2a. The laser emitting apparatus 3 is provided with an oscillator for allowing a laser beam to oscillate. For example, this includes an oscillation stage 4, oscillators 5 and 7, and a lead 6 for oscillation generation.

The oscillators 5 and 7 allow the laser beam to oscillate within a range of an upper-and-lower angle θ and within a right-and-left angle θ', respectively. The periods of them are adjustable. In the case of taking a long period, for example, a mechanism for mechanically causing reciprocating motion is preferable. The laser beam emitted from the laser emitting apparatus 3 is reflected between the reflecting mirror 2 along the arrows illustrated, thereby exciting substances to be reacted, such as the pollutant gases described above, in the reaction cylinder 1 and accelerating the photochemical reactions.

Next, an example applied to the inside of an exhaust gas flue will be described on the basis of Fig. 3.

41 designates an exhaust gas flue, one end of which is connected to a smokestack 42, and the other end of which is connected to a large boiler for thermal power generation with a dust chamber (not shown) interposed therebetween.

Combustion exhaust gas 43 of boiler fuel, which is dusted, typically contains 1000 ppm of sulfur dioxide (SO_2), 250 to 300 ppm of nitric oxides (NO_x), respectively. Photochemical reaction vessel A is formed at directly subsequent stage of the exhaust gas flue 41, as described below. The exhaust gas is treated in the photochemical reaction vessel A and is discharged from the smokestack 42 into the atmosphere as clean gas 44.

Reflecting mirrors 45 are provided on the inner circumferential

surfaces at the subsequent stage of the exhaust gas flue. These use mirrors with plate glasses, for example, in consideration of the corrosion resistance. In addition, other reflecting mirrors 46a and 46b are suspended in the exhaust gas flue 41, facing each other. A window 57 is opened at a part of the exhaust gas flue 41, and a laser emitting apparatus 47 supported by a pin 50 is installed over the window. Further, a hydraulic power system 48 is connected to the laser emitting apparatus 47 through a piston 49 as an oscillator. The piston 49 is allowed to freely move in and out.

As described above, it can be said that the inside of the exhaust gas flue surrounded by the reflecting mirrors forms the photochemical reaction vessel A. It is noted that a mechanism is adopted, in which a gas inlet pipe 51 opens at the entrance side of the vessel, that is, immediately upstream of the reflecting mirror 46a, and oxidant such as air and ozone, or one in which a trace quantity of chloride is added to the oxidant is introduced into the gas flue.

Next, in the structure of the smokestack 42, a reservoir 52 for absorbing solution is provided at the bottom of the smokestack. A conduit 54 for circulation of the absorbing solution extends from one side of the reservoir 52 to the outside of the smokestack 42, goes upward via a pump 53, is again fitted into the smokestack 42 at the upper portion thereof, and is provided with nozzles 55 at the tip portion. For the absorbing solution, an alkaline water solution such as 5% aqueous sodium hydroxide, water, or the like is appropriate, and this is injected from the nozzles 55. 56 designates a mist separator, which is provided above the nozzles 55.

In the above described configuration, the dusted exhaust gas 43 is mixed with the air or ozone from the gas inlet pipe 46 at the upstream of the reflecting mirror 46a, and enters the photoreaction vessel A through the space between the reflecting mirror 46a and the inner wall of the gas flue 41. In the photoreaction vessel A, from the laser emitting apparatus 47 which is rotated about the pin 50 by means of the hydraulic power system 48, a laser beam irradiates all over the photoreaction vessel A with the optical path of the laser beam being changed from moment to moment. That is, the laser beam is reflected between the reflecting mirror 45 and the reflecting mirrors 46a and 46b as illustrated by the arrows, whereby

photons that have not caused the photoreaction are reflected multiple times.

The nitrogen monoxide and sulfur dioxide in the exhaust gas is oxidized into nitrogen dioxide and sulfur trioxide, respectively, by oxidant in the process of photoreaction, and flows into the smokestack 42 through both upper and lower spaces of the downstream reflecting mirror 46b. In the smokestack 42, an absorbing solution, 5% aqueous sodium hydroxide, for example, is sprayed as described above. Nitrogen monoxide, which has not reacted, as well as the above described nitrogen dioxide and sulfur trioxide are absorbed by the water solution. The exhaust gas subjected to absorbing treatment passes the nozzles 55, is removed of its mist by the mist separator 56, and is discharged into the atmosphere as clean gas.

This is the end of the description of the apparatuses of the examples. Next, specific effects in the case where the apparatus is actually used for exhaust gas treatment in a large boiler for thermal power generation will be described.

In the apparatus configuration of Fig. 3, an argon laser emitting apparatus was installed on the top of a gas flue (50 cm x 50 cm) over a window, and reciprocating motion of a laser emitting portion of the above described emitting apparatus in a flow direction of exhaust gas was caused by a hydraulically-operated oscillator one time per second. The combustion exhaust gas was allowed to flow at a speed of 5 m/sec with air being added so that the oxygen concentration of the gas in the gas flue became 5%, while a 0.5 w argon laser (4850 angstrom wavelength) was emitted into the gas flue. It is noted that the exhaust gas roughly contains 1000 ppm of sulfur dioxide, 250 ppm of nitrogen monoxide, and 30 ppm of nitrogen dioxide.

In a smokestack, spraying of a 5% aqueous sodium hydroxide at 3 liter/min from nozzles resulted in that the concentrations in the exhaust gas at the outlet of the smokestack became 100 ppm of sulfur dioxide, 40 ppm of nitrogen monoxide, and 5 ppm of nitrogen dioxide. These were significantly reduced in comparison to the initial concentrations in the exhaust gas. That is, it has been found that the exhaust gas is effectively treated by adopting the apparatus configuration of this invention.

This invention can be changed variously without sticking to details

of the above examples and changing the gist of the invention.

For example, the reflecting mirror is attached to the inner or the outer circumferential surface of the tubular body. In the latter case, a transparent tubular body should be used, of course, but in the former case, this is not necessary. The oscillator only needs to be able to oscillate the laser emitting portion, and the structure of the oscillator is no object. The substances to be reacted to which the photoreaction is applied is not limited to the exhaust gas, sulfur dioxide, nitric oxides, carbon monoxide, and the like, in the examples, of course.

To sum up, the photosynthesis reactor of this invention is characterized by including: a tubular body for containing substance to be reacted, the tubular body provided with a reflecting mirror on the circumferential surface thereof; a laser emitting apparatus installed on the side face of the tubular body over a window; and an oscillator for periodically oscillating a laser beam inside the tubular body, the oscillator attached to the laser emitting apparatus. Because the photosynthesis reactor can irradiate all over the inside of the tubular body with a high light energy laser beam, and the oscillation operation thereof is freely adjustable, it is possible to cause the photoreaction of a large amount of substances to be reacted effectively. For example, when the present invention is applied to the exhaust gas treatment, the pollutants can be surely removed, and there is an advantage that this can be performed economically.

For instance, in the conventional thermal power generation plant, ultra high smokestacks of equal to or more than 200 m have been generally constructed for diffusing the exhaust gases. However, if the apparatus of this invention is adopted, a height of several tens meters will be enough for the smokestack, and the cost of equipment will be significantly reduced.

4. Brief Description of Drawings

The drawings show example apparatuses of this invention, in which: Fig. 1 is a cross-sectional view taken along the line I-I of Fig. 2; Fig. 2 is a longitudinal sectional view taken along the line II-II of Fig. 1; and Fig. 3 is a longitudinal sectional view of another example apparatus.

1...transparent reaction cylinder, 2...reflecting mirror, 3...laser emitting apparatus, 4...oscillation stage, 5 and 7...oscillator, 41...gas flue,

42...smokestack, 43...exhaust gas, 44...clean gas, 45, 46a, and 46b...reflecting mirror, 47...laser emitting apparatus, 51...gas inlet pipe, 52...reservoir for absorbing solution, 55...nozzle, 56...mist separator

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6. List of Attached Documents
(1) Power of Attorney: two
(2) Specification: one
(3) Drawing: one
(4) Copy of Request: one
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Fig.1

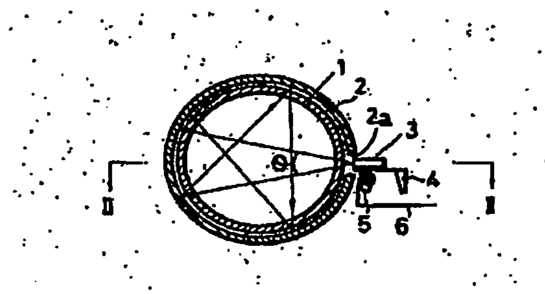

Fig.2

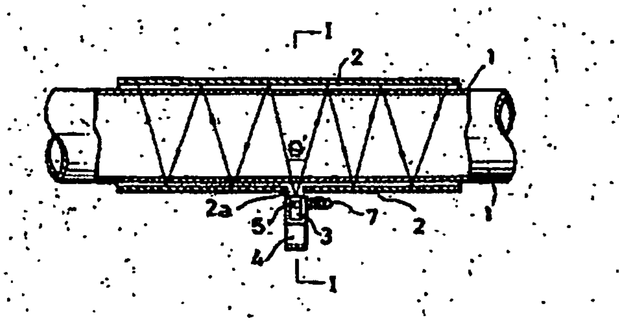

Fig.3